

**Manuscript version: Author's Accepted Manuscript**

The version presented in WRAP is the author's accepted manuscript and may differ from the published version or Version of Record.

**Persistent WRAP URL:**

<http://wrap.warwick.ac.uk/109782>

**How to cite:**

Please refer to published version for the most recent bibliographic citation information. If a published version is known of, the repository item page linked to above, will contain details on accessing it.

**Copyright and reuse:**

The Warwick Research Archive Portal (WRAP) makes this work by researchers of the University of Warwick available open access under the following conditions.

Copyright © and all moral rights to the version of the paper presented here belong to the individual author(s) and/or other copyright owners. To the extent reasonable and practicable the material made available in WRAP has been checked for eligibility before being made available.

Copies of full items can be used for personal research or study, educational, or not-for-profit purposes without prior permission or charge. Provided that the authors, title and full bibliographic details are credited, a hyperlink and/or URL is given for the original metadata page and the content is not changed in any way.

**Publisher's statement:**

Please refer to the repository item page, publisher's statement section, for further information.

For more information, please contact the WRAP Team at: [wrap@warwick.ac.uk](mailto:wrap@warwick.ac.uk).

## Abstract

This study investigated if crying, sleeping or feeding problems that co-occur (multiple regulatory problems) or are persistent predict attention problems and diagnoses of ADHD in childhood and adulthood. Participants were 342 individuals who were assessed at 5, 20 and 56 months for crying, sleeping and feeding (regulatory problems) and at 6, 8 and 28 years for ADHD diagnoses, attention problems and attention span. Infants/toddlers with multiple/persistent regulatory problems had an increased risk of receiving an ADHD diagnosis both in childhood and adulthood compared to those who never had regulatory problems. Multiple/persistent regulatory problems were further associated with a high-decreasing attention problems trajectory from childhood to adulthood. Interventions to alleviate early regulatory problems may prevent the development of attention problems.

## **Early Crying, Sleeping, and Feeding Problems and Trajectories of Attention Problems from Childhood to Adulthood**

ADHD type problems, characterized by hyperactivity-impulsivity and inattention, are common during childhood affecting up to 7% of school-aged children (Boyle et al., 2011). Increasing evidence suggests that ADHD emerges early in the preschool years and is associated with academic underachievement, behavioral problems and poorer social outcomes (Klein et al., 2012). ADHD symptoms in preschool years have been shown to remain moderately stable throughout childhood (Karam et al., 2015; Lavigne, Lebailly, Hopkins, Gouze, & Binns, 2009), start decreasing in the late teenage years (Monuteaux, Mick, Faraone, & Biederman, 2010) but persist into adulthood for a subgroup of those with ADHD in childhood (Breeman, Jaekel, Baumann, Bartmann, & Wolke, 2016). Although a meta-analysis study revealed that the persistence rate of ADHD symptoms into adulthood is approximately 15%, the reported prevalence rates in individual studies vary widely between 4% and 70% (Faraone, Biederman, & Mick, 2006). This variability in the prevalence rate may be explained by the assessment of different subtypes of ADHD since the presentation of ADHD symptoms changes from childhood to adulthood (Faraone et al., 2006). In particular, hyperactivity symptoms are highly prevalent during preschool years but gradually become less evident throughout adolescence and adulthood (Biederman, Mick, & Faraone, 2000; Faraone et al., 2006), whereas attention problems may remain more stable (Biederman et al., 2000; Larsson, Lichtenstein, & Larsson, 2006). Thus, a focus on attention problems may help to identify children who show similar trajectories in attention until adulthood.

Several longitudinal studies have prospectively investigated the development of childhood attention problems and assessed mean symptom levels or proportions of ADHD diagnoses at various time points (Biederman et al., 2000; Hart, Lahey, Loeber, Applegate, & Frick, 1995; Larsson et al., 2006; O'Neill, Rajendran, Mahbubani, & Halperin, 2017;

Rietveld, Hudziak, Bartels, van Beijsterveldt, & Boomsma, 2004). The problem with this approach is that not all individuals may follow the same pattern of development over time. Instead, there may be different subgroups in the target population that follow distinctive trajectories (Pollak, 2015), however there are few studies that have analyzed whether there are trajectories of attention development that subgroups follow. The few studies which determined the trajectories of subgroups over time generally focused on overall ADHD symptoms (Larsson, Dilshad, Lichtenstein, & Barker, 2011; van Lier, van der Ende, Koot, & Verhulst, 2007) or used high-risk or clinical samples (Jester et al., 2005; Malone, Van Eck, Flory, & Lamis, 2010; Nagin & Tremblay, 1999) but usually had short durations of follow-up. Likewise, studies which focused on the trajectories of attention problems in particular had short follow up intervals in which the longest follow up was until adolescence (Arnold et al., 2014; Galera et al., 2011; Larsson et al., 2011; Robbers et al., 2011; Sasser, Calvin, & Bierman, 2016). To illustrate, one study reported on two subgroups who followed a different pattern of attention problems over time from 8 to 17 years (Larsson et al., 2011), while other studies identified three subgroups of attention problems trajectories from 1.5 to 8 years of age (Galera et al., 2011), 6 to 12 years of age (Robbers et al., 2011), from 6-12 to 9-15 years of age (Arnold et al., 2014) and from 8 to 18 years of age (Sasser et al., 2016). None of the studies measured the trajectories of attention problems from childhood to adulthood so far, although it has been suggested that attention problems may follow stable trajectories into adulthood (Breeman et al., 2016).

Even though above mentioned studies clearly indicate that attention problems persist to a moderate degree, existing research generally focused on early predictors of later attention problems at one time point in an individual's life (Biederman et al., 1996; Johnson & Marlow, 2011; Rodriguez et al., 2009) and provided little information regarding the predictors of persistence of attention problems (Caye et al., 2016). Identifying the early

symptoms in infancy/toddlerhood which may differentiate children who are more likely to follow a trajectory of high attention problems from childhood to adulthood would be crucial to identify infants/toddlers at increased risk and to advise practitioners regarding developmentally sensitive early assessments (McGoey, Eckert, & Dupaul, 2002). Two existing studies suggested several factors as predictors of high attention problems trajectory. One study identified parental stress, inconsistent parenting, emotion dysregulation and aggression as predictors of high ADHD trajectory from 8 to 18 years of age (Sasser et al., 2016). A second study (Galera et al., 2011) identified preterm birth, low birthweight, prenatal tobacco exposure, young maternal age, maternal depression, paternal history of antisocial behaviour and non-intact family as predictors of high attention problems trajectory from 17 months to 8 years of age. These studies suggested several predictors relating to individual differences in children and parental behaviour and experiences, all making a small contribution to explain trajectories.

The present study was conceived to investigate specifically whether early individual differences in crying, sleeping and feeding, considered as self-regulation of behavioural state, a prerequisite for prolonged attention, predicts adverse development of attention regulation in childhood and into adulthood.

Human infants are born immature compared to most other mammals. Fussing and crying of the infant secures that parents stay close for safety and it triggers the let-down reflex with milk being released from the mother's breast (Winberg, 2005) to facilitate breastfeeding. Fussing and crying follows a characteristic crying curve in the first three months of life in which crying peaks at 6 weeks (i.e. 2 hours and 15 minutes) and then reduces to approximately 70 minutes by 3 months of age in industrial societies (Wolke, Bilgin, & Samara, 2017). Large individual differences are found right from birth (Barr, 1990) and across societies. The large reduction in fuss/cry behaviour at 3 months coincides with the

first biobehavioural shift (Wolff, 1987) and the development of primary intersubjectivity (Trevathen, 1987), indicating changes in both behavioural control and cognitive abilities in distinguishing oneself and others in interaction. Infants who do not master this transition in acquiring self-soothing and continue to fuss or cry at significantly higher levels after 3 months (i.e. >2 hours per 24 hours) have been considered to have a regulatory problem (von Kries, Kalies, & Papousek, 2006). Similarly, sleep-wake regulation evolves during infancy aided by light alterations, parent interventions and routines and neurophysiological maturation and infants start to sleep less during the day and sleep more during the night (Bamford et al., 1990; Wolke, 1994). All infants wake up 5-7 times per night but there are individual differences in how well infants are able to regulate waking by self-soothing themselves back into sleep (Galland, Taylor, Elder, & Herbison, 2012). By three months of age, many infants are able to use self-soothing skills, which is predictive of long night time sleep (St James-Roberts, Roberts, Hovish, & Owen, 2015). Similar to crying and sleeping, feeding is essential to secure survival of infants (Wolke, 1994). In general, human infants double their weight in the first 3 to 6 months which is entirely driven by food intake (Wolke, 1994). At around 3-4 months infants start to show a preference for salt in food which is low in breast milk and become interested in trying new textures of food (Harris & Booth, 1987; Reilly, 2006). These and other anatomical and physical changes such as oral-motor skills prepare the introduction of new textures of food and have been shown to indicate a sensitive period (Harris & Mason, 2017). The acceptance of textured food requires infants to overcome a natural tendency of neophobia (Bryant-Waugh, Markham, Kreipe, & Walsh, 2010). Again, there are large individual differences and strong indications that infants differ in sensory sensitivity and ability to self-regulate acceptance of new texture and tastes (Farrow & Coulthard, 2018). The abilities to self-regulate crying, sleeping and food intake have been found to occur at 3-6 months after the first bio-behavioural shift (Wolff, 1987).

Originally, it has been noticed that crying, sleeping and feeding regulatory problems (RPs) usually occur together in clinically referred infants, i.e. parents present their infant rarely with one of these RPs alone (Hofacker & Papoušek, 1998; Papoušek, Schieche, & Wurmser, 2007; Wolke, Gray, & Meyer, 1994). Epidemiological studies have further confirmed that these RPs occur together in up to one third of infants with any other RPs (i.e. multiple RPs) and parents of infants with multiple or persistent RPs are more likely to seek professional help since they consider these to be most challenging (von Kries et al., 2006; Wolke, Meyer, Ohrt, & Riegel, 1995). Approximately 2-8% of infants experience multiple RPs beyond three months of age (Schmid, Schreier, Meyer, & Wolke, 2010; St James-Roberts, 2012; von Kries et al., 2006). These infant RPs have been previously associated with the development of attention problems in childhood (Hemmi, Wolke, & Schneider, 2011). Another meta-analysis revealed that children with ADHD had significantly higher bedtime resistance, more sleep onset difficulties, and night awakenings compared to controls when measured using questionnaires (Cortese, Faraone, Konofal, & Lecendreux, 2009). This association remained significant for sleep onset latency and sleep apnea when measured objectively (e.g. actigraphy) (Cortese et al., 2009). Similarly, a recent systematic review suggested that there is strong empirical support for the association between eating disorders and ADHD (Levin & Rawana, 2016). It was suggested that individuals who have an eating disorder are likely to display the main symptoms of ADHD which are inattention, hyperactivity and impulsivity (Farber, 2010; Sala et al., 2017). Individuals with ADHD maybe less attentive to internal signs of hunger (Davis, Levitan, Smith, Tweed, & Curtis, 2006) or feeding problems during infancy may result in neurodevelopmental vulnerabilities with inattention symptoms being an important feature (Galler et al., 2012).

In particular, multiple RPs (Becker, Holtmann, Laucht, & Schmidt, 2004; Bilgin & Wolke, 2016; Hemmi et al., 2011) or persistent RPs have been repeatedly reported to be

associated with ADHD type problems up to adolescence (Becker et al., 2004; Hyde, O'Callaghan, Bor, Williams, & Najman, 2012; Schmid & Wolke, 2014). However, previous studies either had short follow-up periods, small sample sizes, or used retrospective designs (Becker et al., 2004; Desantis, Coster, Bigsby, & Lester, 2004; O'Callaghan et al., 2010; Thunström, 2002). Thus, it remains unknown if multiple/persistent RPs in infancy/toddlerhood have far reaching consequences and are still associated with attention problems in adulthood.

The association between RPs and attention problems may be explained by shared features, risk factors and neurobiological mechanism. To start with, infants/toddlers with multiple or persistent RPs have difficulties to inhibit a current state such as crying and night waking (Hemmi et al., 2011), which leads them to be distressed for long periods of time (St James-Roberts, 2012). The ability to return to a settled awake state is a prerequisite to attend to external stimuli for prolonged periods. Likewise, children with attention problems have difficulties inhibiting stimuli and regulating their attention to focus on a task at hand. Second, both RPs and attention problems are predicted by the same prenatal risk factors ranging from premature birth to increased maternal stress and alterations in HPA function (Banerjee, Middleton, & Faraone, 2007; Bolten et al., 2013; Petzoldt et al., 2014) as well as environmental risk factors such as psychosocial problems and family adversity (Biederman, Faraone, & Monuteaux, 2002; Schmid et al., 2010; Thunström, 2002; Wurmser et al., 2006). Lastly, RPs are suggested to share common underlying neurobiological mechanism with attention problems. For instance, alterations were found in the same brain regions in both patients with eating disorders (Frank, 2013) and ADHD (Bush, Valera, & Seidman, 2005). Furthermore, dopaminergic system and prefrontal cortex functions have been found to play an important role in both sleeping difficulties and ADHD (Cassoff, Wiebe, & Gruber, 2012).



Converging evidence suggests that both multiple or persistent RPs and attention problems might be phenotypes of underlying developmental neural dysregulation, i.e., problems to regulate or inhibit on-going behaviour and corresponding brain activity (Bush, 2010; Schmid & Wolke, 2014). Untested is whether early infant multiple/persistent RPs might indeed be associated with different trajectories of varying levels of attention problems through childhood and adulthood.

Overall, the aim of this prospective study over nearly three decades was first, to examine whether infants/toddlers with multiple/persistent RPs have more attention problems, lower attention span, and higher odds for ADHD diagnoses in adulthood than those without any infant regulatory problems. Second, to examine whether multiple/persistent RPs during infancy/toddlerhood predict stable attention problem and attention span trajectories from childhood to adulthood.

## **METHODS**

### **Study Design and Participants**

The Bavarian Longitudinal Study (BLS) is a prospective geographically defined whole population sample of neonatal at-risk children born between January 1985 and March 1986 in Southern Bavaria (Germany) (Wolke, Ratschinski, Ohrt, & Riegel, 1994).

The present study utilizes data collected from birth to adulthood (Appendix 1 in the Supplement). From the 1495 children invited for the 6-year assessment, for the prospective case-control follow-up study in adulthood we excluded childhood participants who had at any time a single or non-persistent RP or where there were any missing data on crying, sleeping or feeding problems at any time at assessment from 5 to 56 months (Figure 1). Of the eligible 708 participants for this prospective case-control study, we were able to follow up 342 individuals at a mean age of 27.6 ( $SD = 1.8$ ,  $range = 25-31$ ) years. 311 participants who

never had RPs and 55 participants who had multiple/persistent RPs were lost to follow up (eTable 1). Participants who did not complete the study in the never RP group differed from participants who remained in the study in that they had parents with lower socioeconomic status ( $p < .01$ ). Participants who did not complete the study in the multiple/persistent RPs group differed from participants who remained in the study in that they had significantly lower gestational age ( $p < .001$ ) and birth weight ( $p < .001$ ) and had parents of lower socioeconomic status ( $p < .05$ ).

Ethical approval for the study was granted by the ethics committees of the University of Munich Children's Hospital, the Bavarian Health Council (Landesärtekammer Bayern), and the University Hospital Bonn. Informed consent was obtained from parents (childhood) and participants (adulthood).

## **Measures**

### **Multiple/Persistent Regulatory Problems**

As part of a neurodevelopmental assessment, research paediatricians asked parents via a standard interview about their children's crying, sleeping, and feeding problems at age 5 months. At 20 and 56 months, sleeping and eating problems were assessed via standardized parental interviews and neurological examinations of oral motor function conducted by paediatricians. Paediatricians had been trained to achieve an inter-rater reliability  $>90\%$  and received three-monthly booster workshops in order to maintain high reliability throughout the data collection period. The assessments at 5 and 20 months were carried out corrected for prematurity, and the assessment at 56 months was carried out according to chronological age (Schmid et al., 2010). The definitions for crying, feeding and sleeping problems at 5 months and sleeping and eating problems at 20 and 56 months are given in eTable 2 in the Supplement.

Children with multiple RPs were those who had at least two problems at 5 months and they were dichotomized into two groups: 0= never, 1= multiple RPs. Persistent RPs were defined as having at least one problem at 5, 20 and 56 months and they were dichotomized into two groups: 0= never, 1= persistent RPs. Subsequently, multiple and/or persistent RPs were combined and coded into a binary variable: 0= never RPs, 1= multiple or persistent RPs (eTable 2 in the Supplement).

### **Parent/Self rated attention problems**

Parents, mostly mothers (88%), rated their children's attention problems at 6 and 8 years using the validated attention problems subscale of the German version of the Child Behavior Checklist (CBCL) (Achenbach, 1991; Arbeitsgruppe Deutsche Child Behavior Checklist, 1998a). In adulthood (25-31 years), participants rated their attention problems using the German version of the Young Adult Self-Report (YASR) (Achenbach, 1997; Arbeitsgruppe Deutsche Child Behavior Checklist, 1998b). At each assessment, items were rated on a scale from 0 (*not true*) to 2 (*very or often true*) and then summed into a total score with higher scores indicating more attention problems.

The informant differed in childhood (parent report) compared to adulthood (self-report). Nevertheless, it is a common practice to use parent reports for children and self-reports for adults who are mostly not living with their parents anymore (Faraone et al., 2006). In addition, age-appropriate versions of the same scale were used in childhood and adulthood.

### **Observer-rated attention span**

Psychologists rated the child's attention span using the Tester's Rating of Child Behavior (TRCB) (Wolke, 1996) at 6 years and 8 years and the Tester's Rating of Adult Behavior (TRAB) (Wolke, 2012) in adulthood (Jaekel, Wolke, & Bartmann, 2013). Both in childhood and adulthood attention span was judged during a cognitive assessment lasting one hour. Additionally, it was judged across all tasks during the assessment day in adulthood (Breeman

et al., 2016; Jaekel et al., 2013). Psychologists scored the individual's attention on a scale from 1 (very short attention span) to 9 (very long attention span). Attention span scores showed moderate reliability at all assessment points ( $ICC_{6y} = .67$ ;  $ICC_{8y} = .72$ ;  $ICC_{28y} = .66$ ).

**ADHD diagnoses.** ADHD diagnoses at 6 and 8 years were made according to the structured and validated Mannheim Parent Interview (Esser, Blanz, Geisel, & Laucht, 1989) that allowed for a clinical DSM-IV diagnosis. All raters were trained to greater 90% inter-rater agreement (Jaekel, Baumann, Bartmann, & Wolke, 2018). The presence of ADHD diagnosis in adulthood was made with the DSM-IV based adult ADHD rating scale completed by participants (Kooij et al., 2005). This adult ADHD rating scale is considered a valid measure of ADHD and associated psychosocial impairment in adulthood (Kooij et al., 2005).

According to guidelines by the authors (Kooij et al., 2005), adults exhibiting four out of nine inattentive symptoms or four out of nine hyperactivity/impulsivity symptoms 'often' or 'very often' are considered significantly impaired. Thus, they received a diagnosis of predominantly inattentive (ADHD-IA), predominantly hyperactive-impulsive (ADHD-HI), or ADHD combined type (ADHD-C).

### **Descriptives and Covariates**

Gestational age, sex (male) and socioeconomic status (SES) were included as covariates since they have previously been shown associations with attention problems. Gestational age at birth was determined from maternal reports of the last menstrual period and serial ultrasounds during pregnancy. Information on family SES at birth was collected via structured parental interviews and computed as a weighted composite score derived from the occupation of the head of each family (usually the father) together with the highest educational qualification held by either parent into three categories of low, medium and high SES (Bauer, 1988). Moreover, age at assessment in adulthood was included as a covariate to adjust for the age range in adulthood assessment.

## Statistical Analysis

To examine the differences between infants/toddlers with multiple/persistent RPs and infants/toddlers who never had RPs, we performed independent sample t-tests for continuous variables and  $X^2$  test for categorical variables using SPSS 24.

Longitudinal attention problems and attention span trajectories were analyzed with latent class growth analysis (LCGA) using Mplus (version 8) to identify distinct groups of individuals based on their attention trajectories. LCGA is a special case of growth mixture modelling that assumes homogeneity of growth parameters within each latent subgroup (Muthen & Muthen, 2000). This approach discerns homogenous classes defined by different developmental trajectories of attention (Jung & Wickrama, 2008), which is useful in identifying how different groups of people who share common characteristic develop over time. The Full Information Maximum Likelihood (FIML) approach was used to handle missing data.

In order to determine the optimal number of latent classes, we examined several model fit indices: Bayesian Information Criterion (BIC) and Akaike Information Criterion (AIC), Lo-Mendell-Rubin (LMR), Vuong-Lo-Mendell-Rubin (VLMR) and the entropy value (Jung & Wickrama, 2008). Briefly, we started with one class and compared these fit indices to the fit indices of a successively greater number of trajectory classes until a greater number of classes did not result in improved fit values. In addition to statistical model fit indices, several other criteria were considered to determine the optimal number of latent classes, i.e. the probability of belonging to a latent class should be 0.80 or higher; the smallest class should include at least 5% to 10% of the sample; parsimony of models, their interpretability and theoretical justification, and the substantive relevance of class should be considered. Gestational age, sex (male), SES and age at assessment in adulthood were treated as potential covariates. We used automatic R3STEP approach to model auxiliary variables, which adjusts for the impact of

covariates while estimating the number of latent classes and shown to produce less-biased estimates than traditional methods (Vermunt, 2010). The statistical significance was set at  $p < .05$ .

## **RESULTS**

### **Final Sample Characteristics**

Eighty-three participants had multiple/persistent RPs (24.3%) and 259 (75.7%) never had RPs. The group of participants with multiple/persistent RPs ( $N = 83$ ) consisted of 38 (45.8%) who had persistent RPs, 34 (41%) who had multiple RPs and 11 (13.2%) who had both multiple and persistent RPs. Eleven (13.6%) had RPs at one measurement point, 21 (25.9%) participants had RPs at two measurement points and 49 (60.5%) had RPs at three measurement points (eTable 3 in the Supplement). There were no significant differences between infants/toddlers with multiple/persistent RPs and those who never had RPs on the majority of demographics variables (Table 1). However, infants/toddlers with multiple/persistent RPs were older at the adulthood assessment than those who never had RPs (Table 1).

### **Do infants/toddlers with multiple/persistent regulatory problems have more attention problems in childhood and adulthood?**

Infants/toddlers with multiple/persistent RPs had higher attention problem scores both in childhood (CBCL) and adulthood (YASR) in comparison to those who never experienced RPs (Table 2). Although there were no significant differences between the two groups during childhood in attention span (TRCB), infants/toddlers with multiple/persistent RPs had significantly lower attention span scores in adulthood (TRAB) compared to those who never

experienced RPs (Table 2). Moreover, Figure 2 shows that significantly more infants/toddlers with multiple/persistent RPs had ADHD diagnoses in childhood and adulthood than those who never had RPs. In addition, infants/toddlers with multiple/persistent RPs more often had specific ADHD diagnoses both in childhood and adulthood. At 6 years of age (OR= 2.92, 95% CI= 1.20-7.05) and in adulthood (OR= 4.00, 95% CI= 1.18-13.67), they were more likely to have predominantly inattentive subtype, whereas at 8 years of age (OR= 3.26, 95% CI= 1.03-10.32) they were more likely to have predominantly hyperactivity/impulsivity diagnoses.

**Do multiple/persistent regulatory problems during infancy/toddlerhood predict stable attention problems and attention span trajectories across adulthood?**

*Attention Problems Trajectory Classes*

Likelihood ratio tests (LMR and VLMR) and fit indices (BIC and AIC) suggested that a three-class model was a significantly better fit than the two-class alternative (Table 3). However, classification precision (entropy) results suggested that the two-class model was better able to represent attention problems rather than the three-class alternative. Because the three-class model provided the better statistical model, we decided to explore the three-class model using a sensitivity analysis, in order to examine whether there were actually three distinct classes (Appendix 2 in the Supplement). Due to lower posterior probabilities and unclear class distinctiveness, we decided to select the two-class model. Therefore, the initial series of latent class growth analyses (LCGA) suggested two distinct underlying patterns of attention problems within participants from childhood to adulthood, which we labelled as “high-decreasing attention problems” and “low attention problems” (Figure 3). 87.2% of the children were found to display consistently low levels of attention problems, whereas 12.8%

exhibited a pattern of attention problems that were consistently high but decreasing towards adulthood.

### ***Attention Span Trajectory Classes***

Likelihood ratio tests (LMR and VLMR) and suggested that a two-class model was significantly better fit than the one-class and alternative (Table 3). Furthermore, a two-class model showed lower fit indices (BIC and AIC) compared to three-class model (Table 3). Moreover, there was no significant improvement in the model fit for the three-class model.

The two distinctive patterns of attention span from childhood to adulthood that were identified from the initial series of LCGA are shown in Figure 3. 74% of the participants were found to have consistently medium levels of attention span, whereas 26% exhibited a pattern of attention span, which starts at medium level at 6 years but continues to increase until adulthood.

### ***Predicting Attention Problems and Attention Span Trajectory Class Membership by Multiple/Persistent RPs***

Multiple/persistent RPs were significantly associated with the high-decreasing attention problems trajectory from childhood to adulthood (OR= 1.18, 95% CI= 1.02-2.37). On the other hand, there was no significant association between early multiple/persistent RPs and the levels of attention span trajectories from childhood to adulthood. Rather than multiple/persistent RPs, low gestation (OR= 0.32, 95% CI= 0.22-0.41) was associated with the medium attention span trajectory.

## **Discussion**

The current study found that multiple/persistent RPs are associated with increased odds of ADHD diagnoses and attention problems from childhood to adulthood, along with decreased



attention span in adulthood. We identified two trajectories of attention problems from childhood to adulthood: low and high-decreasing. Moreover, we identified two trajectories of attention span from childhood to adulthood: medium and medium-increasing.

Multiple/persistent RPs were associated with high-decreasing attention problems trajectory from childhood to adulthood.

Findings of this study add further support for the association between early RPs and increased childhood attention problems (Schmid & Wolke, 2014) and extend the literature by showing that the impact of early RPs on attention problems is still apparent in adulthood. Attention problems decreased from childhood to adulthood as previously reported (Faraone et al., 2006), and ADHD diagnoses were more frequent at 8 years (school age) compared to 6 years (preschool) and adulthood. Attention problem scores were higher and ADHD diagnoses were more frequent in adults who had multiple/persistent RPs in early childhood compared to those who never had RPs at any assessment points. Although these findings are strong for parent rated attention problems in childhood, they are weaker for observed attention span in a testing situation. This could be due to the fact that parents were the shared informant for both RPs and attention problems. Difference in observer-blind attention span between infants/toddlers with multiple/persistent RPs and those who never had RPs was only apparent in adulthood. Nevertheless, this difference was reduced when covariates were introduced. Lower gestational age was associated with decreased attention span and age of assessment in adulthood was associated with increased attention span in accordance with previous literature (Breeman et al., 2016).

Even though the majority of the studies on inattention trajectories revealed three subgroups who shared a similar development of attention problems over time (Arnold et al., 2014; Galera et al., 2011; Robbers et al., 2011; Sasser et al., 2016), our study identified two classes. A similar number of trajectories were identified in a large population based twin study

(Larsson et al., 2011), with a high-increasing trajectory and a low trajectory when assessed at 8-9, 13-14 and 16-17 years of age. This finding of a high-increasing trajectory was different from the high-decreasing trajectory identified in the current study, however a decreasing trajectory might be more in line with normative developmental expectations during adulthood in comparison to adolescence (Faraone et al., 2006).

The finding that multiple and/or persistent RPs during infancy/toddlerhood distinguished trajectories of high-decreasing attention problems from childhood to adulthood suggests that problems in behavioural regulation during infancy is related to regulation problems in adulthood. The stability in trait is supported by the studies showing an association between crying, sleeping and feeding problems during infancy and ADHD in adulthood (Galler et al., 2012; Thunström, 2002). This also might suggest that initial multiple and/or persistent deficits in regulatory competences might be an early phenotype for attention problems (Schmid & Wolke, 2014). This supports a developmental cascade in which persistent differences in behavior maximally affect the next most proximate phase of development, which in turn affects the following phase (Bornstein, Hahn, & Wolke, 2013; Hyde et al., 2012). Initial persistent deficits in regulatory competences might be early markers for similar processes of attention in childhood (Barkley, 1997). Thus, rather than assuming that a given risk factor such as early RP (i.e., at one time point) directly predicts later attention problems, a cascade model of development suggests that infant behaviour provides the starting point of a trajectory of dysregulation through time of domain-related age-appropriate constructs towards a mature phenotype (Bornstein et al., 2013; Holtmann et al., 2011). However, it also means that, on average, multiple/persistent regulatory problems are set on a developmental journey of higher attention problems. However, this direction may be altered by appropriate intervention at each point on this journey. It also may suggest that the early the trajectory is interrupted and altered, the easier this trajectory can be changed.

There are alternative explanations. Firstly, the presence of a particular gene polymorphism of the dopaminergic system has been reported in both attention problems in childhood (El-Faddagh, Laucht, Maras, Vohringer, & Schmidt, 2004) and regulatory problems in infancy (Becker, El-Faddagh, Schmidt, & Laucht, 2007). However, the evidence is based on small sample sizes and needs replication studying both attention problems and regulatory problems. Secondly, maladaptive parenting such as low maternal sensitivity may increase infant RPs (Degangi, Porges, Sickel, & Greenspan, 1993). However, the limited evidence so far indicates that RPs occur despite sensitive parenting or may even adversely affect sensitive parenting (Bilgin & Wolke, 2017; Philbrook & Teti, 2016). Thirdly, neurodevelopmental factors that are both associated with RPs and attention problems, such as lower gestational age may be responsible for the association between RPs and attention problems. Indeed, those of lower gestational age have been reported to have slightly raised rates of RPs (Bilgin & Wolke, 2016) and attention problems (Aarnoudse-Moens, Weisglas-Kuperus, van Goudoever, & Oosterlaan, 2009). However, in the analysis we controlled for gestational age and the findings were only slightly altered. In particular, multiple and/or persistent RPs appear to be a stable individual difference that affect regulation of attention across childhood into adulthood.

### **Strengths and Limitations**

There are several strengths of this study. The design of this study is prospective from infancy to adulthood. Moreover, this study included multiple measures and data sources in a large sample of individuals who had multiple/persistent RPs and controls. There are also limitations. First, RPs were not assessed via structured diaries. However, this might not be possible in general population samples due to high drop-out rates in diary studies (Barr, Kramer, Boisjoly, McVey-White, & Pless, 1988). Second, the sample of the current study included preterm and full-term infants. However we controlled for gestational age and the

differences in rates on RPs have been found to be small between even very preterm infants and full term (Bilgin & Wolke, 2016). Third, different versions of the same scales were used in childhood and adulthood assessments for both attention problems and attention span. The difficulty in the measurement of the same behaviour from childhood to adulthood using the exact same measure has been acknowledged by other researchers (Caye et al., 2016).

However, the same constructs were used with comparable scales and scoring was adapted according to age, just like IQ-tests assess similar constructs (e.g. performance IQ) but have to use items of higher difficulty with advancing age from childhood into adulthood. Since the current study measured attention across different developmental periods, the difference in the manifestation of attention problems were needed to be taken into consideration in the assessments. This is essential to construct a developmentally appropriate assessment.

## **Conclusion**

To conclude, the impact of multiple/persistent RPs in infancy and toddlers on attention problems persist into adulthood. Assessments of crying, sleeping and feeding problems should be conducted by paediatricians at regular intervals during infancy and toddlerhood to identify those who might be at risk of developing attention problems. This is important due to the fact that untreated attention problems can have high social and societal costs such as academic and occupational underachievement, delinquency, and difficulties with personal relationships (Barkley, 2006). Early interventions for infant or toddler RPs may help prevent an adverse developmental cascade culminating in a chronic attention problems pathways.

## References

- Aarnoudse-Moens, C. S., Weisglas-Kuperus, N., van Goudoever, J. B., & Oosterlaan, J. (2009). Meta-analysis of neurobehavioral outcomes in very preterm and/or very low birth weight children. *Pediatrics*, 124, 717-728. doi:10.1542/peds.2008-2816
- Achenbach, T. M. (1991). *The manual for the Child Behavior Checklist 4-18 and 1991 Profile*. University of Vermont, Department of Psychiatry. Burlington, VT.
- Achenbach, T. M. (1997). *Manual for the Young Adult Self-Report and Young Adult Behavior Checklist*. University of Vermont, Department of Psychiatry. Burlington, VT.
- Arbeitsgruppe Deutsche Child Behavior Checklist (1998a). Elternfragebogen über das Verhalten von Kindern und Jugendlichen: Deutsche Bearbeitung der Child Behavior Checklist (CBCL/4-18). Arbeitsgruppe Kinder-, Jugend- und Familiendiagnostik. Köln, Germany.
- Arbeitsgruppe Deutsche Child Behavior Checklist (1998b). Fragebogen für junge Erwachsene (YASR) Arbeitsgruppe Kinder-, Jugend- und Familiendiagnostik (KJFD). Köln.
- Arnold, L. E., Ganocy, S. J., Mount, K., Youngstrom, E. A., Frazier, T., Fristad, M., . . . Marsh, L. (2014). Three-year latent class trajectories of attention-deficit/hyperactivity disorder (ADHD) symptoms in a clinical sample not selected for ADHD. *Journal of the American Academy of Child and Adolescent Psychiatry*, 53, 745-760. doi:10.1016/j.jaac.2014.03.007
- Bamford, F. N., Bannister, R. P., Benjamin, C. M., Hillier, V. F., Ward, B. S., & Moore, W. M. O. (1990). Sleep In The First Year Of Life. *Developmental Medicine & Child Neurology*, 32, 718-724. doi:doi:10.1111/j.1469-8749.1990.tb08432.x

- Banerjee, T. D., Middleton, F., & Faraone, S. V. (2007). Environmental risk factors for attention-deficit hyperactivity disorder. *Acta Paediatrica*, 96, 1269-1274.  
doi:10.1111/j.1651-2227.2007.00430.x
- Barkley, R. A. (1997). Behavioral inhibition, sustained attention, and executive functions: constructing a unifying theory of ADHD. *Psychological Bulletin*, 121, 65-94.
- Barkley, R. A. (2006). *Attention-deficit hyperactivity disorder: A handbook for diagnosis and treatment*, 3rd ed. New York, NY, US: Guilford Press.
- Barr, R. G. (1990). The normal crying curve: what do we really know? *Developmental Medicine & Child Neurology*, 32, 356-362.
- Barr, R. G., Kramer, M. S., Boisjoly, C., McVey-White, L., & Pless, I. B. (1988). Parental diary of infant cry and fuss behaviour. *Archives of Disease in Childhood*, 63, 380-387.
- Bauer, A. (1988). *Ein Verfahren zur Messung des für das Bildungsverhalten relevanten Status (BRSS)*. Frankfurt: Deutsches Institut für Internationale Pädagogische Forschung.
- Becker, K., El-Faddagh, M., Schmidt, M. H., & Laucht, M. (2007). [Dopaminergic polymorphisms and regulatory problems in infancy]. *Zeitschrift Kinder Jugendpsychiatrie und Psychotherapie*, 35, 145-151. doi:10.1024/1422-4917.35.2.145
- Becker, K., Holtmann, M., Laucht, M., & Schmidt, M. H. (2004). Are regulatory problems in infancy precursors of later hyperkinetic symptoms? *Acta Paediatrica*, 93, 1463-1469.  
doi:10.1080/08035250410015259
- Biederman, J., Faraone, S., Milberger, S., Curtis, S., Chen, L., Marrs, A., . . . Spencer, T. (1996). Predictors of persistence and remission of ADHD into adolescence: results from a four-year prospective follow-up study. *Journal of the American Academy of*

*Child and Adolescent Psychiatry*, 35, 343-351. doi:10.1097/00004583-199603000-00016

Biederman, J., Mick, E., & Faraone, S. V. (2000). Age-dependent decline of symptoms of attention deficit hyperactivity disorder: impact of remission definition and symptom type. *The American Journal of Psychiatry*, 157, 816-818.  
doi:10.1176/appi.ajp.157.5.816

Bilgin, A., & Wolke, D. (2016). Regulatory problems in very preterm and full-term infants over the first 18 months. *Journal of Developmental & Behavioral Pediatrics*, 37, 298-305. doi:10.1097/dbp.0000000000000297

Bilgin, A., & Wolke, D. (2017). Development of comorbid crying, sleeping, feeding problems across infancy: Neurodevelopmental vulnerability and parenting. *Early Human Development*, 109, 37-43. doi:10.1016/j.earlhumdev.2017.04.002

Bolten, M., Nast, I., Skrundz, M., Stadler, C., Hellhammer, D. H., & Meinlschmidt, G. (2013). Prenatal programming of emotion regulation: neonatal reactivity as a differential susceptibility factor moderating the outcome of prenatal cortisol levels. *Journal of Psychosomatic Research*, 75, 351-357.  
doi:10.1016/j.jpsychores.2013.04.014

Bornstein, M. H., Hahn, C. S., & Wolke, D. (2013). Systems and cascades in cognitive development and academic achievement. *Child Development*, 84, 154-162.  
doi:10.1111/j.1467-8624.2012.01849.x

Boyle, C. A., Boulet, S., Schieve, L. A., Cohen, R. A., Blumberg, S. J., Yeargin-Allsopp, M., . . . Kogan, M. D. (2011). Trends in the prevalence of developmental disabilities in US children, 1997–2008. *Pediatrics*, 127, 1034-1042. doi:10.1542/peds.2010-2989

Breeman, L. D., Jaekel, J., Baumann, N., Bartmann, P., & Wolke, D. (2016). Attention problems in very preterm children from childhood to adulthood: the Bavarian

- Longitudinal Study. *Journal of Child Psychology & Psychiatry*, 57, 132-140.  
doi:10.1111/jcpp.12456
- Bryant-Waugh, R., Markham, L., Kreipe, R. E., & Walsh, B. T. (2010). Feeding and eating disorders in childhood. *International Journal of Eating Disorders*, 43, 98-111.  
doi:10.1002/eat.20795
- Bush, G. (2010). Attention-Deficit/Hyperactivity Disorder and attention networks. *Neuropsychopharmacology*, 35, 278-300. doi:10.1038/npp.2009.120
- Bush, G., Valera, E. M., & Seidman, L. J. (2005). Functional neuroimaging of attention-deficit/hyperactivity disorder: a review and suggested future directions. *Biological Psychiatry*, 57, 1273-1284. doi:10.1016/j.biopsych.2005.01.034
- Cassoff, J., Wiebe, S. T., & Gruber, R. (2012). Sleep patterns and the risk for ADHD: a review. *Nature and Science of Sleep*, 4, 73-80. doi:10.2147/nss.s31269
- Caye, A., Rocha, T. B., Anselmi, L., Murray, J., Menezes, A. M., Barros, F. C., . . . Rohde, L. A. (2016). Attention-Deficit/Hyperactivity Disorder trajectories from childhood to young adulthood: Evidence from a birth cohort supporting a late-onset Syndrome. *JAMA Psychiatry*, 73, 705-712. doi:10.1001/jamapsychiatry.2016.0383
- Cortese, S., Faraone, S. V., Konofal, E., & Lecendreux, M. (2009). Sleep in children with attention-deficit/hyperactivity disorder: meta-analysis of subjective and objective studies. *Journal of the American Academy of Child and Adolescent Psychiatry*, 48, 894-908. doi:10.1097/CHI.0b013e3181ac09c9
- Davis, C., Levitan, R. D., Smith, M., Tweed, S., & Curtis, C. (2006). Associations among overeating, overweight, and attention deficit/hyperactivity disorder: A structural equation modelling approach. *Eating Behaviors*, 7(3), 266–274.



- Degangi, G. A., Porges, S. W., Sickel, R. Z., & Greenspan, S. I. (1993). Four-year follow-up of a sample of regulatory disordered infants. *Infant Mental Health Journal*, 14, 330-343. doi:10.1002/1097-0355(199324)14:4<330::AID-IMHJ2280140407>3.0.CO;2-K
- Desantis, A., Coster, W., Bigsby, R., & Lester, B. (2004). Colic and Fussing in Infancy, and Sensory Processing at 3 to 8 Years of Age. *Infant Mental Health Journal*, 25, 522-539. doi:<http://dx.doi.org/10.1002/imhj.20025>
- El-Faddagh, M., Laucht, M., Maras, A., Vohringer, L., & Schmidt, M. H. (2004). Association of dopamine D4 receptor (DRD4) gene with attention-deficit/hyperactivity disorder (ADHD) in a high-risk community sample: a longitudinal study from birth to 11 years of age. *Journal of Neural Transmission*, 111, 883-889. doi:10.1007/s00702-003-0054-2
- Esser, G., Blanz, B., Geisel, B., & Laucht, M. (1989). *Mannheimer Elterninterview : Strukturiertes interview zur erfassung von kinderpsychiatrischen auffalligkeiten*. Beltz, Germany: Weinheim.
- Faraone, S. V., Biederman, J., & Mick, E. (2006). The age-dependent decline of attention deficit hyperactivity disorder: a meta-analysis of follow-up studies. *Psychological Medicine*, 36, 159-165. doi:10.1017/s003329170500471x
- Farber, S. K. (2010). The comorbidity of eating disorders and attention-deficit hyperactivity disorder. *Eating Disorders*, 18, 81-89. doi:10.1080/10640260903439623
- Farrow, C., & Coulthard, H. (2018). 11 - Multisensory evaluation and the neophobic food response A2 - Reilly, Steve *Food Neophobia* (pp. 219-236): Woodhead Publishing.
- Frank, G. K. (2013). Altered brain reward circuits in eating disorders: chicken or egg? *Current Psychiatry Reports*, 15, 396. doi:10.1007/s11920-013-0396-x
- Galera, C., Cote, S. M., Bouvard, M. P., Pingault, J. B., Melchior, M., Michel, G., . . . Tremblay, R. E. (2011). Early risk factors for hyperactivity-impulsivity and

- inattention trajectories from age 17 months to 8 years. *Archives of General Psychiatry*, 68, 1267-1275. doi:10.1001/archgenpsychiatry.2011.138
- Galland, B. C., Taylor, B. J., Elder, D. E., & Herbison, P. (2012). Normal sleep patterns in infants and children: a systematic review of observational studies. *Sleep Medicine Reviews*, 16, 213-222. doi:10.1016/j.smrv.2011.06.001
- Galler, J. R., Bryce, C. P., Zichlin, M. L., Fitzmaurice, G., Eaglesfield, G. D., & Waber, D. (2012). Infant malnutrition is associated with persisting attention deficits in middle adulthood. *The Journal of Nutrition*, 142(4), 788-794. doi: 10.3945/jn.111.145441
- Harris, G., & Booth, D. A. (1987). Infants' preference for salt in food: Its dependence upon recent dietary experience. *Journal of Reproductive and Infant Psychology*, 5, 97-104. doi:10.1080/02646838708403479
- Harris, G., & Mason, S. (2017). Are there sensitive periods for food acceptance in infancy? *Current Nutrition Reports*, 6, 190-196. doi:10.1007/s13668-017-0203-0
- Hart, E. L., Lahey, B. B., Loeber, R., Applegate, B., & Frick, P. J. (1995). Developmental change in attention-deficit hyperactivity disorder in boys: a four-year longitudinal study. *Journal of Abnormal Child Psychology*, 23, 729-749.
- Hemmi, M. H., Wolke, D., & Schneider, S. (2011). Associations between problems with crying, sleeping and/or feeding in infancy and long-term behavioural outcomes in childhood: a meta-analysis. *Archives of Disease in Childhood*, 96, 622-629. doi:10.1136/adc.2010.191312
- Hofacker, N. v., & Papoušek, M. (1998). Disorders of excessive crying, feeding, and sleeping: The Munich Interdisciplinary Research and Intervention Program. *Infant Mental Health Journal*, 19, 180-201. doi:doi:10.1002/(SICI)1097-0355(199822)19:2<180::AID-IMHJ7>3.0.CO;2-S

- Holtmann, M., Buchmann, A. F., Esser, G., Schmidt, M. H., Banaschewski, T., & Laucht, M. (2011). The Child Behavior Checklist-Dysregulation Profile predicts substance use, suicidality, and functional impairment: a longitudinal analysis. *Journal of Child Psychology & Psychiatry*, 52, 139-147. doi:10.1111/j.1469-7610.2010.02309.x
- Hyde, R., O'Callaghan, M. J., Bor, W., Williams, G. M., & Najman, J. M. (2012). Long-term outcomes of infant behavioral dysregulation. *Pediatrics*, 130, 1243-1251. doi:10.1542/peds.2010-3517
- Jaekel, J., Baumann, N., Bartmann, P., & Wolke, D. (2018). Mood and anxiety disorders in very preterm/very low-birth weight individuals from 6 to 26 years. *Journal of Child Psychology and Psychiatry*, 59, 88-95. doi:doi:10.1111/jcpp.12787
- Jaekel, J., Wolke, D., & Bartmann, P. (2013). Poor attention rather than hyperactivity/impulsivity predicts academic achievement in very preterm and full-term adolescents. *Psychological Medicine*, 43, 183-196. doi:10.1017/s0033291712001031
- Jester, J. M., Nigg, J. T., Adams, K., Fitzgerald, H. E., Puttler, L. I., Wong, M. M., & Zucker, R. A. (2005). Inattention/hyperactivity and aggression from early childhood to adolescence: heterogeneity of trajectories and differential influence of family environment characteristics. *Development and Psychopathology*, 17, 99-125.
- Johnson, S., & Marlow, N. (2011). Preterm birth and childhood psychiatric disorders. *Pediatric Research*, 69, 11R. doi:10.1203/PDR.0b013e318212faa0
- Jung, T., & Wickrama, K. (2008). An introduction to latent class growth analysis and growth mixture modeling. *Social and Personality Psychology Compass*, 2, 302-317.
- Karam, R. G., Breda, V., Picon, F. A., Rovaris, D. L., Victor, M. M., Salgado, C. A., . . . Bau, C. H. (2015). Persistence and remission of ADHD during adulthood: a 7-year clinical

- follow-up study. *Psychological Medicine*, 45, 2045-2056.  
doi:10.1017/s0033291714003183
- Klein, R. G., Mannuzza, S., Olazagasti, M. A., Roizen, E., Hutchison, J. A., Lashua, E. C., & Castellanos, F. X. (2012). Clinical and functional outcome of childhood attention-deficit/hyperactivity disorder 33 years later. *Archives of General Psychiatry*, 69, 1295-1303. doi:10.1001/archgenpsychiatry.2012.271
- Kooij, J. J., Buitelaar, J. K., van den Oord, E. J., Furer, J. W., Rijnders, C. A., & Houdiamont, P. P. (2005). Internal and external validity of attention-deficit hyperactivity disorder in a population-based sample of adults. *Psychological Medicine*, 35, 817-827.
- Larsson, H., Dilshad, R., Lichtenstein, P., & Barker, E. D. (2011). Developmental trajectories of DSM-IV symptoms of attention-deficit/hyperactivity disorder: genetic effects, family risk and associated psychopathology. *Journal of Child Psychology & Psychiatry*, 52, 954-963. doi:10.1111/j.1469-7610.2011.02379.x
- Larsson, H., Lichtenstein, P., & Larsson, J. O. (2006). Genetic contributions to the development of ADHD subtypes from childhood to adolescence. *Journal of the American Academy of Child and Adolescent Psychiatry*, 45, 973-981.  
doi:10.1097/01.chi.0000222787.57100.d8
- Lavigne, J. V., LeBailly, S. A., Hopkins, J., Gouze, K. R., & Binns, H. J. (2009). The prevalence of ADHD, ODD, depression, and anxiety in a community sample of 4-year-olds. *Journal of Clinical Child & Adolescent Psychol*, 38, 315-328.  
doi:10.1080/15374410902851382
- Levin, R. L., & Rawana, J. S. (2016). Attention-deficit/hyperactivity disorder and eating disorders across the lifespan: A systematic review of the literature. *Clinical Psychology Review*, 50, 22-36. doi:10.1016/j.cpr.2016.09.010

- Malone, P. S., Van Eck, K., Flory, K., & Lamis, D. A. (2010). A mixture-model approach to linking ADHD to adolescent onset of illicit drug use. *Developmental Psychology*, *46*, 1543-1555. doi:10.1037/a0020549
- McGoey, K. E., Eckert, T. L., & Dupaul, G. J. (2002). Early intervention for preschool-age children with ADHD: A literature review. *Journal of Emotional and Behavioral Disorders*, *10*, 14-28. doi:10.1177/106342660201000103
- Monuteaux, M. C., Mick, E., Faraone, S. V., & Biederman, J. (2010). The influence of sex on the course and psychiatric correlates of ADHD from childhood to adolescence: a longitudinal study. *Journal of Child Psychology & Psychiatry*, *51*, 233-241. doi:10.1111/j.1469-7610.2009.02152.x
- Muthen, B., & Muthen, L. K. (2000). Integrating person-centered and variable-centered analyses: growth mixture modeling with latent trajectory classes. *Alcoholism: Clinical and Experimental Research*, *24*, 882-891.
- Nagin, D., & Tremblay, R. E. (1999). Trajectories of boys' physical aggression, opposition, and hyperactivity on the path to physically violent and nonviolent juvenile delinquency. *Child Development*, *70*, 1181-1196.
- O'Callaghan, F. V., Al Mamun, A., O'Callaghan, M., Clavarino, A., Williams, G. M., Bor, W., . . . Najman, J. M. (2010). The link between sleep problems in infancy and early childhood and attention problems at 5 and 14 years: Evidence from a birth cohort study. *Early Human Development*, *86*, 419-424. doi:10.1016/j.earlhumdev.2010.05.020
- O'Neill, S., Rajendran, K., Mahbubani, S. M., & Halperin, J. M. (2017). Preschool Predictors of ADHD Symptoms and Impairment During Childhood and Adolescence. *Current Psychiatry Reports*, *19*, 95. doi:10.1007/s11920-017-0853-z

- Papoušek, M., Schieche, M., & Wurmser, H. . (2007). *Disorders of Behavioral and Emotional Regulation in the First Years of Life: Early Risks and Intervention in the Developing Parent—Infant Relationship*. Bern: Huber.
- Petzoldt, J., Wittchen, H. U., Wittich, J., Einsle, F., Hofler, M., & Martini, J. (2014). Maternal anxiety disorders predict excessive infant crying: a prospective longitudinal study. *Archives of Disease in Childhood*, 99, 800-806. doi:10.1136/archdischild-2013-305562
- Philbrook, L. E., & Teti, D. M. (2016). Bidirectional associations between bedtime parenting and infant sleep: Parenting quality, parenting practices, and their interaction. *Journal of Family Psychology*, 30, 431-441. doi:10.1037/fam0000198
- Pollak, S. D. (2015). Developmental psychopathology: recent advances and future challenges. *World Psychiatry*, 14, 262-269. doi:doi:10.1002/wps.20237
- Reilly, S., Skuse, D., & Wolke, D. (2006). The nature and consequences of feeding problems in infancy. In P. J. C. A. Stein (Ed.), *Childhood Feeding Problems and Adolescent Eating Disorders* (pp. 7-40). London: Routledge.
- Rietveld, M. J., Hudziak, J. J., Bartels, M., van Beijsterveldt, C. E., & Boomsma, D. I. (2004). Heritability of attention problems in children: longitudinal results from a study of twins, age 3 to 12. *Journal of Child Psychology & Psychiatry*, 45, 577-588.
- Robbers, S. C. C., van Oort, F. V. A., Polderman, T. J. C., Bartels, M., Boomsma, D. I., Verhulst, F. C., . . . Huizink, A. C. (2011). Trajectories of CBCL attention problems in childhood. *European Child & Adolescent Psychiatry*, 20, 419-427. doi:10.1007/s00787-011-0194-0
- Rodriguez, A., Olsen, J., Kotimaa, A. J., Kaakinen, M., Moilanen, I., Henriksen, T. B., . . . Jarvelin, M. R. (2009). Is prenatal alcohol exposure related to inattention and hyperactivity symptoms in children? Disentangling the effects of social adversity.

*Journal of Child Psychology & Psychiatry*, 50, 1073-1083. doi:10.1111/j.1469-7610.2009.02071.x

Sala, L., Martinotti, G., Carenti, M. L., Romo, L., Oumaya, M., Pham-Scottez, A., . . . Janiri, L. (2017). Attention-deficit/hyperactivity disorder symptoms and psychological comorbidity in eating disorder patients. *Eating and Weight Disorders*. doi:10.1007/s40519-017-0395-8

Sasser, T. R., Kalvin, C. B., & Bierman, K. L. (2016). Developmental trajectories of clinically significant attention-deficit/hyperactivity disorder (ADHD) symptoms from grade 3 through 12 in a high-risk sample: Predictors and outcomes. *Journal of Abnormal Psychology*, 125, 207-219. doi:10.1037/abn0000112

Schmid, G., Schreier, A., Meyer, R., & Wolke, D. (2010). A prospective study on the persistence of infant crying, sleeping and feeding problems and preschool behaviour. *Acta Paediatrica*, 99, 286-290. doi:10.1111/j.1651-2227.2009.01572.x

Schmid, G., & Wolke, D. (2014). Preschool regulatory problems and attention-deficit/hyperactivity and cognitive deficits at school age in children born at risk: Different phenotypes of dysregulation? *Early Human Development*, 90, 399-405. doi:<http://dx.doi.org/10.1016/j.earlhumdev.2014.05.001>

St James-Roberts, I. (2012). *The origins, prevention and treatment of infant crying and sleeping problems*. East Sussex: Routledge.

St James-Roberts, I., Roberts, M., Hovish, K., & Owen, C. (2015). Video evidence that London infants can resettle themselves back to sleep after waking in the night, as well as sleep for long periods, by 3 months of age. *Journal of Development & Behavioral Pediatrics*, 36, 324-329. doi:10.1097/dbp.0000000000000166

- Thunström, M. (2002). Severe sleep problems in infancy associated with subsequent development of attention-deficit/hyperactivity disorder at 5.5 years of age. *Acta Paediatrica*, 91, 584-592. doi:10.1111/j.1651-2227.2002.tb03281.x
- Trevathen, C. (1987). Sharing makes sense: intersubjectivity and the making of an infant's meaning. In R. S. T. Threadgold (Ed.), *Language topics in Honor of Michael Halliday* (Vol. 1, pp. 177-199). Philadelphia: John Benjamins.
- van Lier, P. A., van der Ende, J., Koot, H. M., & Verhulst, F. C. (2007). Which better predicts conduct problems? The relationship of trajectories of conduct problems with ODD and ADHD symptoms from childhood into adolescence. *Journal of Child Psychology & Psychiatry*, 48, 601-608. doi:10.1111/j.1469-7610.2006.01724.x
- Vermunt, J. K. (2010). Latent Class Modeling with Covariates: Two Improved Three-Step Approaches. *Political Analysis*, 18, 450-469.
- von Kries, R., Kalies, H., & Papousek, M. (2006). Excessive crying beyond 3 months may herald other features of multiple regulatory problems. *Archives of Pediatrics & Adolescent Medicine*, 160, 508-511. doi:10.1001/archpedi.160.5.508
- Winberg, J. (2005). Mother and newborn baby: mutual regulation of physiology and behavior--a selective review. *Developmental Psychobiology*, 47, 217-229. doi:10.1002/dev.20094
- Wolff, P. H. (1987). *The development of behavioural states and the expression of emotions in early infancy*. London: University of Chicago Press.
- Wolke, D. (1994). Feeding and sleeping across the lifespan. In M. R. D. Hay (Ed.), *Development through life: a handbook for clinicians* (pp. 517-557). Oxford: Blackwell Scientific Publications.
- Wolke, D. (1996). *TRCB tester's rating of child behavior: Test construction and standardisation (In German)*. Available from the author upon request.



- Wolke, D. (2012). *TRAB tester's rating of adult behavior (in German)*. Available from the author upon request.
- Wolke, D., Bilgin, A., & Samara, M. (2017). Systematic review and meta-analysis: Fussing and crying durations and prevalence of colic in infants. *The Journal of Pediatrics*, 185, 55-61.e54. doi:10.1016/j.jpeds.2017.02.020
- Wolke, D., Gray, P., & Meyer, R. (1994). Excessive infant crying: a controlled study of mothers helping mothers. *Pediatrics*, 94, 322-332.
- Wolke, D., Meyer, R., Ohrt, B., & Riegel, K. (1995). Co-morbidity of crying and feeding problems with sleeping problems in infancy: Concurrent and predictive associations. *Early Development and Parenting*, 4, 191-207. doi:doi:10.1002/edp.2430040405
- Wolke, D., Ratschinski, G., Ohrt, B., & Riegel, K. (1994). The cognitive outcome of very preterm infants may be poorer than often reported: an empirical investigation of how methodological issues make a big difference. *European Journal of Pediatrics*, 153, 906-915.

Table 1. Demographics of the Sample

	Multiple/Persistent RPs (N= 83)	Never (N= 259)	p
GA (weeks): M (SD)	36.71 (4.39)	36.73 (4.17)	.97
BW (gr): M (SD)	2611.27 (950.80)	2704.88 (959.59)	.44
SGA: N (%)	24 (28.9%)	53 (20.5%)	.11
Male: N (%)	40 (48.2%)	131 (50.6%)	.71
Maternal Age (years): M (SD)	29.3 (5.03)	28.9 (5/03)	.55
SES: N (%)			
SES-high	26 (31.3%)	81 (31.3%)	.99
SES- middle	33 (39.8%)	111 (42.9%)	.62
SES- low	24 (28.9%)	67 (25.9%)	.59
Age at assessment in adulthood (years): M (SD)	28.14 (1.9)	27.43 (1.8)	.002

GA, gestational age; BW, birth weight; SGA, small for gestational age. SES, socioeconomic status; reported values are either means and standard deviations or frequencies and percentages.

Table 2. Comparison of the Attention Problems, Attention Span and ADHD Diagnosis between Children with and without Multiple/Persistent Regulatory Problems

	6 years			8 years			25-31 years		
	Multiple/Persistent (N= 83)	No MRP/Persistent (N=259)	p	Multiple/Persistent (N= 83)	No MRP/Persistent (N=259)	p	Multiple/Persistent (N= 83)	No MRP/Persistent (N=259)	p
Attention Problems <sup>a</sup> : M (SD)	4.1 (3.1)	2.7 (2.5)	<b>&lt;.001</b>	2.5 (2.6)	1.8 (2.1)	<b>.02</b>	2.9 (2.3)	2.1 (1.9)	<b>.002</b>
Attention Span <sup>b</sup> : M (SD)	6.00 (1.91)	6.04 (1.7)	.694	6.4 (1.5)	6.6 (1.4)	.29	7.0 (1.5)	7.5 (1.3)	<b>.004</b>
ADHD Diagnosis  (N/%)	16 (19.3%)	24 (9.3%)	<b>.014</b>	20 (24.1%)	34 (13.1%)	<b>.02</b>	15 (9.4%)	24 (19.0%)	<b>.021</b>

<sup>a</sup>Parent report at 6 and 8 Years and self-report at 25-31 years; <sup>b</sup>Observer rated

**Table 3.** Model fit indices of Latent Class Growth Analysis (LCGA) estimated within attention problems and attention span from childhood to adulthood

	Number of Classes	Bayesian Information Criteria (BIC)	Akaike Information Criteria (AIC)	Lo-Mendell-Rubin (LMR) p value	Vuong-Lo-Mendell-Rubin (VLMR) p value	Parametric Bootstrapped Likelihood Ratio Test	Entropy	Number of subjects per class
Attention problems	1	4444.33	4413.70	-	-	-	-	340
	2	4405.36	4363.24	.09	.08	<.001	.86	38/302
	3	4387.52	4333.92	.01	.01	<.001	.82	30/188/122
	4	4389.32	4324.23	.54	.52	<.001	.79	239/46/38/17
Attention Span	1	3487.94	3457.33	-	-	-	-	339
	2	3472.25	3430.16	.002	.002	<.001	.68	83/256
	3	3480.77	3427.21	.17	.15	.19	.68	96/209/34
	4	3492.89	3427.86	.76	.75	.66	.66	114/116/22/57

Figure 1. Flow diagram of participants

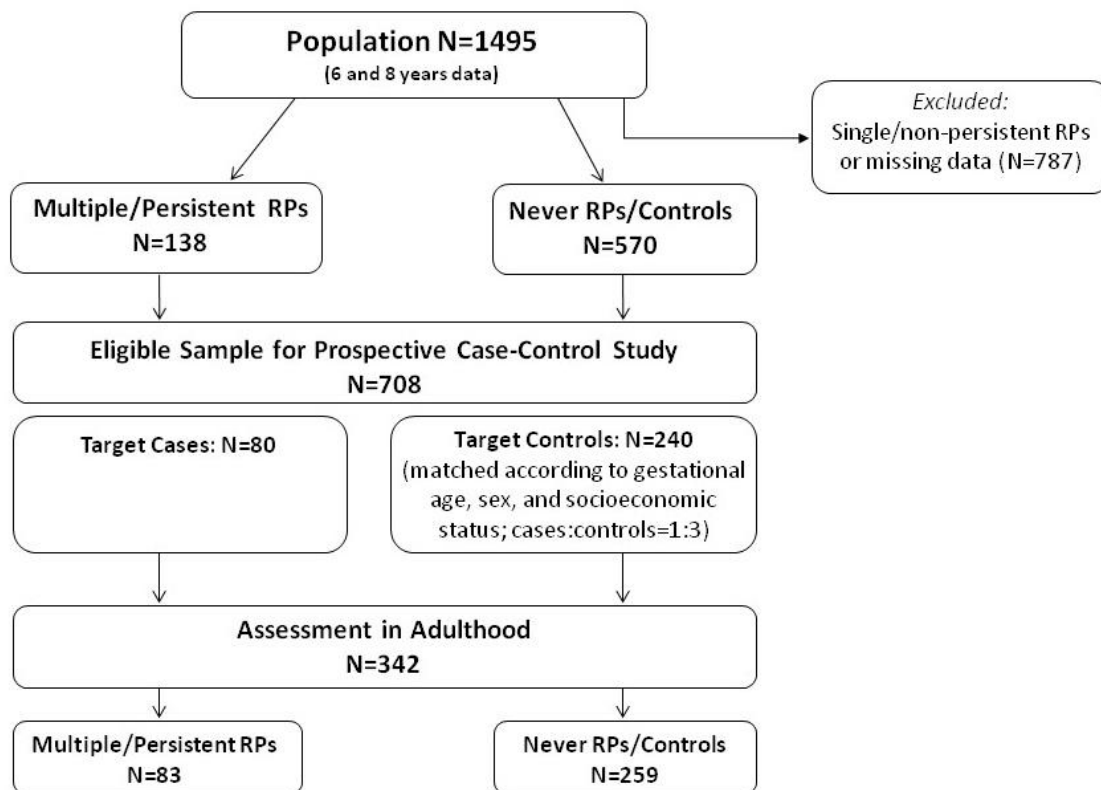


Figure 2. Percentage of ADHD diagnoses at 6, 8, and 25-31 years in infants who had multiple/persistent RP and who did not

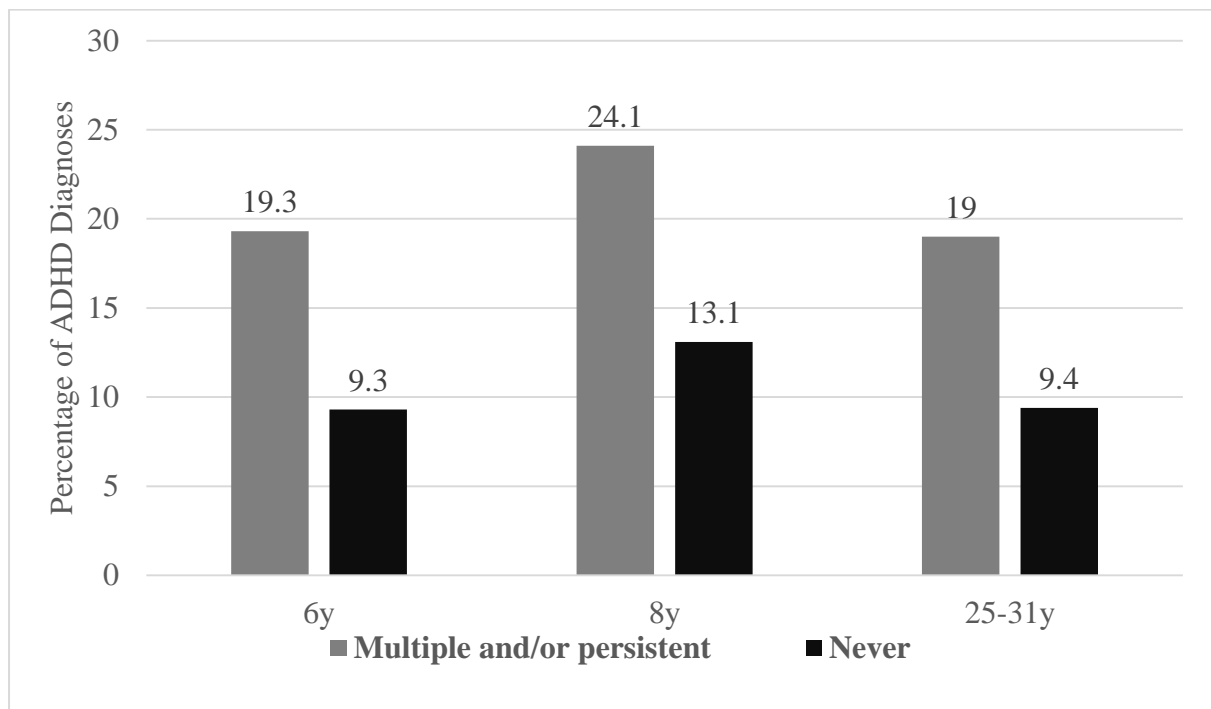
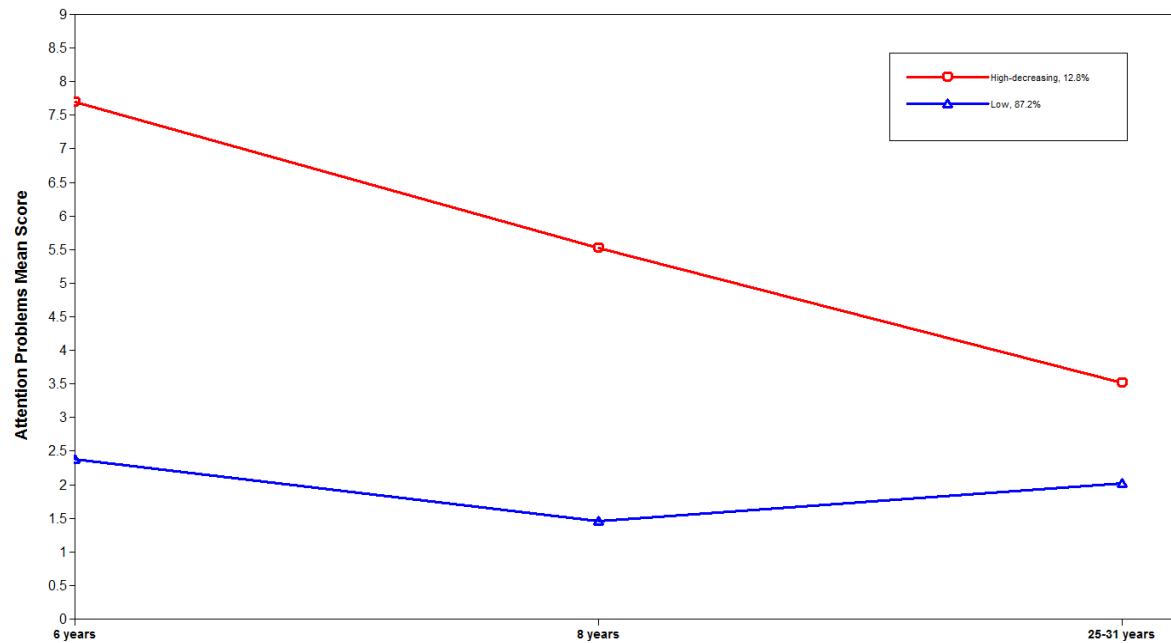


Figure 3. Distinctive trajectories of attention problems (A) and attention span (B) from childhood to adulthood

**A**



**B**

